ASIAN UPPER MANTLE P-WAVE VELOCITY STRUCTURE FROM THE ANALYSIS OF BROADBAND WAVEFORMS

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Contract # F49620-94-1-0050

Abstract

Upper mantle P-wave velocity structure beneath Asia was inferred by modelling high-quality broadband P and PP seismograms at distances 10° to 55°. Data were obtained from IRIS-GSN, CDSN and IRIS-PASSCAL instruments. We regionalized the Asian continent by fitting long-period filtered data to reflectivity synthetics computed for one-dimensional velocity models. Results show that major tectonic provinces can be characterized by single average regional velocity models. These average regional models reveal significant differences in crustal thickness, mantle lid, and low velocity zone properties, and thus will affect seismic discriminants. The data were then filtered less severely to model details of the broadband data and reveal lateral heterogeneity within a tectonic province. Structure of the Tibetan Plateau was studied in detail using regional data recorded at CDSN and GSN stations. Future work will include more broadband P- as well as S-wave modelling.

Key words: Asia, regionalization, crust and upper mantle structure

Objective

Seismic event discrimination methods, such as those relevant to CTBT monitoring, are strongly dependent on the structure of the crust and upper mantle. Thus, the transportability of discriminants is affected by regional differences in crust and upper mantle structures, particularly the nature of the mantle lid and possible low velocity zone (e.g. Beckers, Schwartz and Lay, 1993). The waveforms of P, PP, S and SS body-waves in the distance range 10° to 55° are very sensitive to the seismic velocity structure of the uppermost 200 km of the Earth (i.e. the crust and upper mantle lid and low velocity zone).

Recent deployments of IRIS-GSN, CDSN and IRIS-PASSCAL instrumentation in Asia and efforts by the IRIS-DMC to make these data available now make it possible to gather high-quality, modern data at these critical distances for many regions that were previously unsampled by historical data (e.g. WWSSN, SRO). The objective of this research is to determine one-dimensional crust and upper mantle structures that accurately predict the observed P, PP, S and SS waveforms. The Asian continent consists of many distinct tectonic units (figure 1). We regionalized Asia using the upper mantle velocity models shown in Figure 2. As the path density increases we will be able to infer laterally varying structures. The use of the new data will improve the regionalization of Asia. The impact of various upper mantle models on regional seismic wave propagation will be studied and related to discriminant analysis and transportablity.

Research Accomplished

1. Data and Modelling Strategy

Broadband three-component recordings of crustal events occurring within the Asian continent were extracted from IRIS-FARM products. We searched for moderately large (M_W = 5.5-6.8) events with known mechanisms and simple source-time functions. Instrument deconvolved displacement seismograms were previewed and judged for source complexity and good signal-to-noise. The source parameters (i.e. event depth, focal mechanism and source-time duration) were evaluated and possibly adjusted by modelling broadband waveforms of teleseismic P using WKBJ synthetics.

We modelled the observed waveforms for those events with well constrained source parameters. Synthetics were computed using the reflectivity method. It has been shown (Schwartz and Lay, 1991) that reflectivity is superior to ray-based methods for synthesizing the surface reflected PP phase, which consists of interfering multiple reflections and conversions (e.g. whispering gallery waves).

Synthetics were computed for each event-station pair for seven models of the upper mantle. These models (figure 2) represent a wide range of tectonic character from shield-like models (e.g S25, Lefevre and Helmberger, 1989; and K8, Given and Helmberger, 1980) to models for tectonically active regions (e.g. T7, Burdick and Helmberger, 1978 and WCH, Beckers et. al., 1994). Data and synthetics were convolved with a WWSSN long-period instrument response and compared by aligning the main P-wave arrival. The best fitting models were found by (subjectively) evaluating the relative timing and amplitude of the triplicated P or PP arrival, the PP-P differential time and the character of early coda.

2. Modelling Results: Regionalization of Asia

The Asian continent was regionalized based on the best-fitting model to the observed P and/or PP waveforms. The results are summarized for the distance range 8° to 26° in figure 3. (Results for PP in the distance range 26° to 50° will be shown in the poster.) The best-fitting models separate into the major tectonic provinces of Asia (compare with figure 1).

Specific regions and their upper mantle structures are described below:

The **Tibetan Plateau** (model TP) is characterized by a thick crust (65 km), high Pn velocity (8.23 km/s) and a strong low velocity zone.

Western China (model WCH), corresponding to the North China Fold System and parts of the Eastern Platforms, is characterized by moderately thick crust (50 km), moderately high Pn velocities (8.15 km/s) and a slight low velocity zone.

Siberia and Eurasia (models NCH and K8) are characterized by a more shield-like model: normal crustal thickness and normal to high Pn velocity (40 km and 8.0-8.2 km/s,. respectively) and a positive lid gradient. This model also fits the PP path along the southern margin of the Tibetan Plateau (Indian Shield) and some paths through eastern China.

Eastern Asia (model CHE) is characterized by normal crustal thickness and Pn velocity (35 km and 8.12 km/s, respectively) and a constant lid velocity with no low velocity zone.

3. The Tibetan Plateau

Broadband three-component recordings of regional events in the Tibetan Plateau were extracted from IRIS-FARM products. The stations KMI, LZH, WMQ, XAN, ENH and CHTO are situated around the Plateau such that structure of the Tibetan Plateau and its margins can be studied using events that occurred within Tibet. In particular, the Pn velocity and velocity gradient of the mantle lid was investigated using data recorded at these stations from events in Southern Tibet.

Figure 4 shows the paths from three events to regional stations. We assumed a crustal thickness and velocity of 65 km and 6.4 km/s, respectively, and computed synthetics for a suite of upper mantle velocity models. Using four Pn velocities (8.05, 8.10, 8.15 and 8.20 km/s) and three mantle lid gradients (constant lid velocity, CLV; and positive lid gradients, PLG, of 0.001/s and 0.002/s), we computed reflectivity synthetics for the paths shown in figure 4. These Pn velocities are consistent with the range of velocities for this region inferred from Pn tomography by McNamara et. al. (1994).

Data for nearly all the paths were best fit by the low Pn velocity (8.05 km/s) and a constant lid velocity. The data for paths to KMI revealed differences in lid structure. The waveforms from the southern two events to KMI were best fit by a constant lid velocity (CLV) and Pn velocity of 8.05 km/s. The waveform from the northern event to KMI (shown as dashed line in figure 4) was best fit by a positive lid gradient (PLG) and a Pn velocity of 8.2 km/s. The southern paths sample the northern margin of the Indian Shield, while the northern path samples the southern margin of the Tibetan Plateau. The increased Pn velocity and mantle lid gradient of the northern path relative to the southern path probably results from the mantle responding to the additional load of material due to undertrusting of the Indian Plate or crustal shortening as previously inferred by Holt and Wallace (1980). These results, although preliminary, show that the modern data can be used to further investigate details of the mantle lid structure beneath Tibet.

Data from the IRIS-PASSCAL field experiment on the Tibetan Plateau are available in the IRIS-DMC TIPLT data product (Owens, et. al., 1993). We have only begun to work with the TIPLT data, however the recordings are of very high quality and promise to elucidate the crustal and upper mantle structure beneath the Plateau. A major advantage of these data over the GSN data is that the paths for regional Tibetan events to these stations all lie within the Plateau and do not cross tectonic boundaries. Preliminary results using these data will be presented at the poster.

Conclusions and Recommendations

Our preliminary results for the regionalization of Asia indicate that large areas can be characterized by single average regional upper mantle velocity models. The regions correspond fairly well with the known provinces of surface tectonics. The average regional models differ significantly in the uppermost 200 km and will affect event discrimination techniques. We have shown the results of processing only six (6) events. There are many more data to collect and process and future work will help fill in un-sampled areas.

S-wave data has been extracted and processed for many events, however modelling the data with synthetics has not yet been started. Future work will include S-wave modelling.

As the path density increases it may be possible to formulate a grid search and/or waveform inversion scheme in which the best-fitting average regional model to the long-period filtered data is used as a starting model. Along path average one-dimensional (1D) structure could be found for each path starting with the long-period filtered data, iterating through linearized inversions for 1D structure while gradually including shorter periods. Three-dimensional (3D) upper mantle structure could be inferred by projecting the best-fitting one-dimensional models onto three-dimensional space and solving for the best-fitting 3D model.

Finally, we plan on investigating the effects of our inferred upper mantle structures on regional seismic wave propagation. This will extend the previous work of Beckers et. al. (1993).

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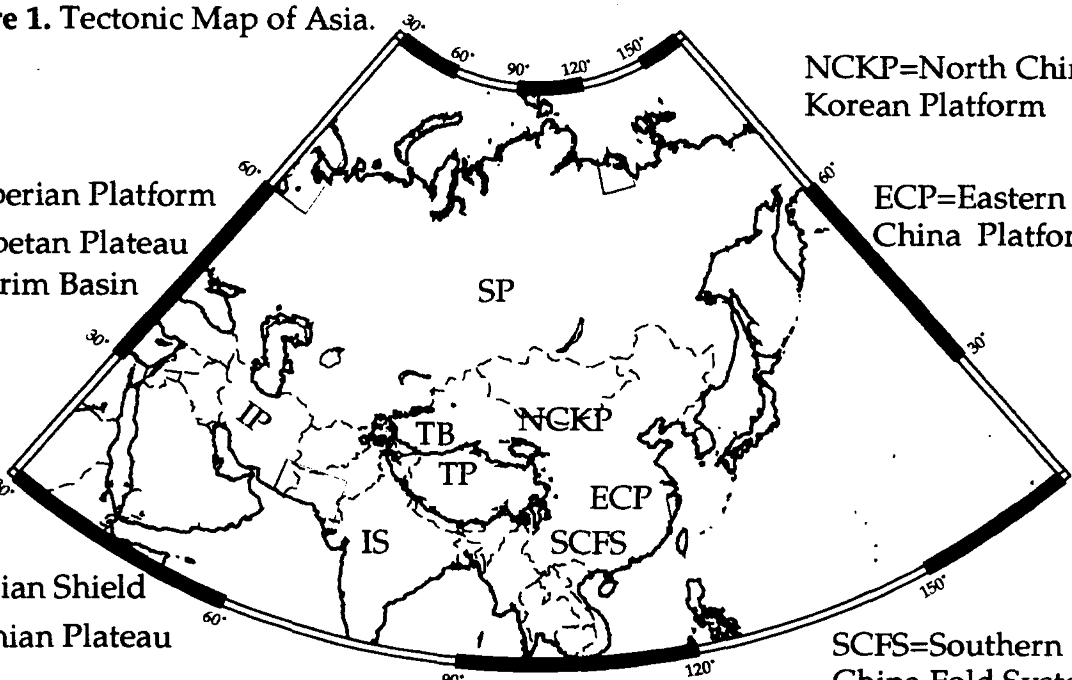
Figure 1. Tectonic Map of Asia.



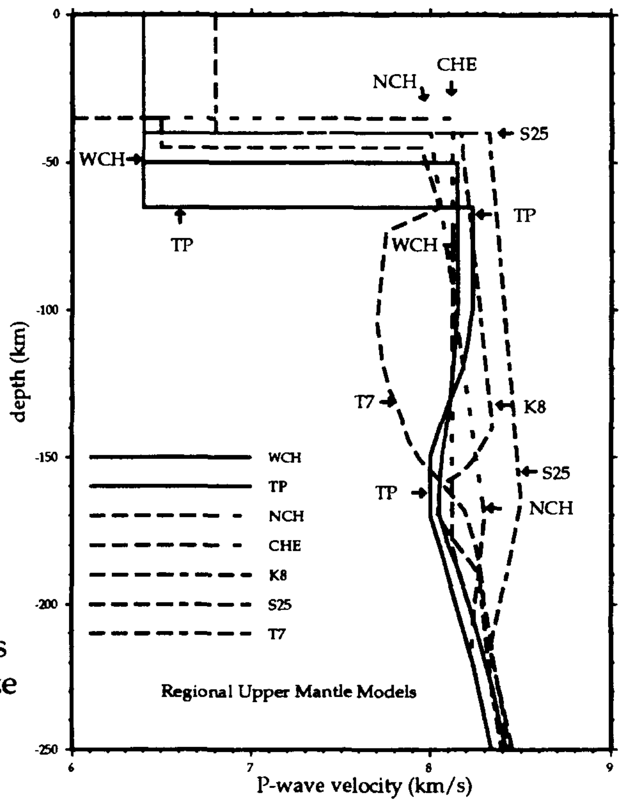


Figure 2. Upper mantle models used in this study to regionalize the Asian continent.

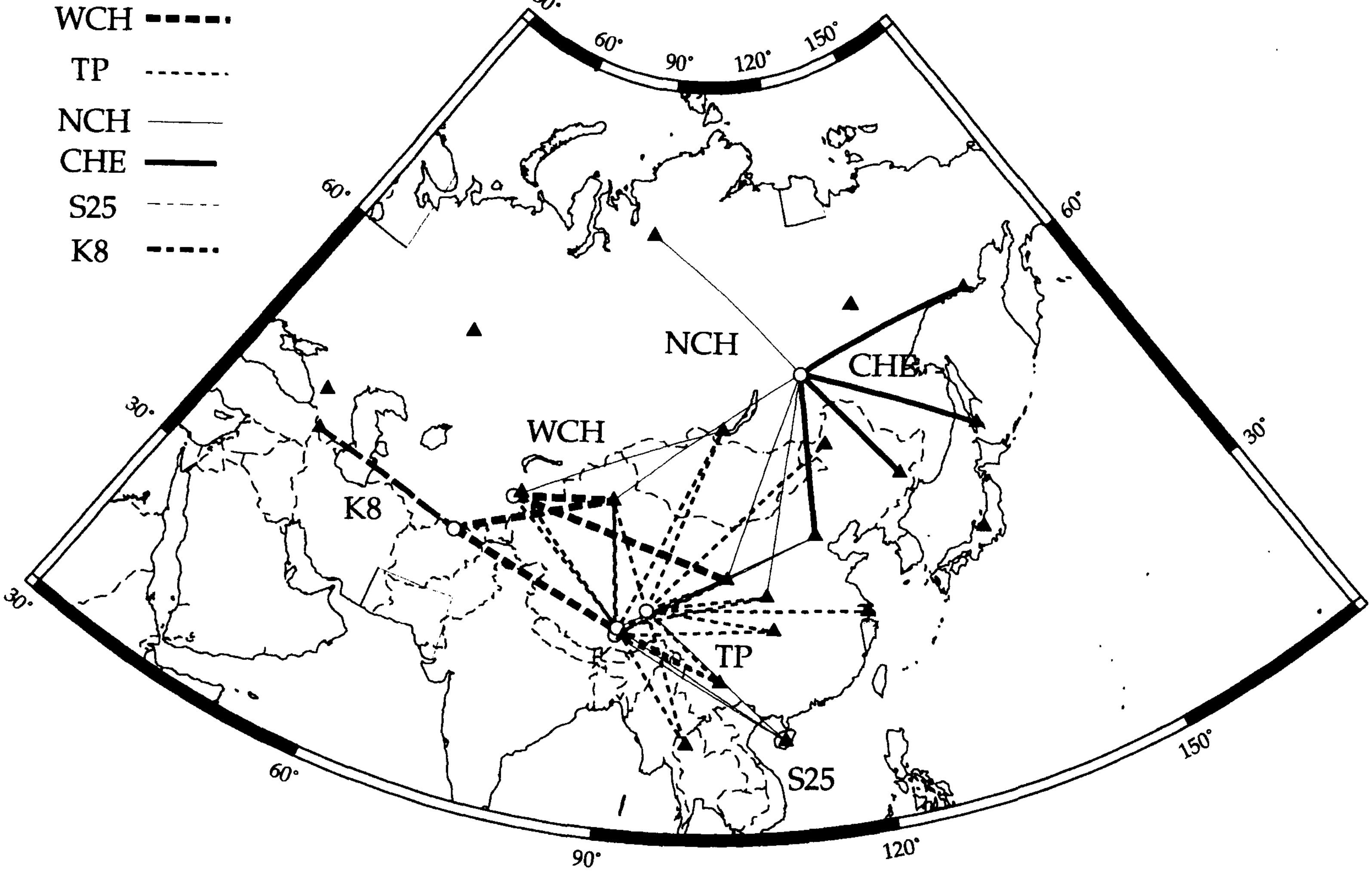


Figure 3. Best-fitting regional models for P, Δ=8°-26°

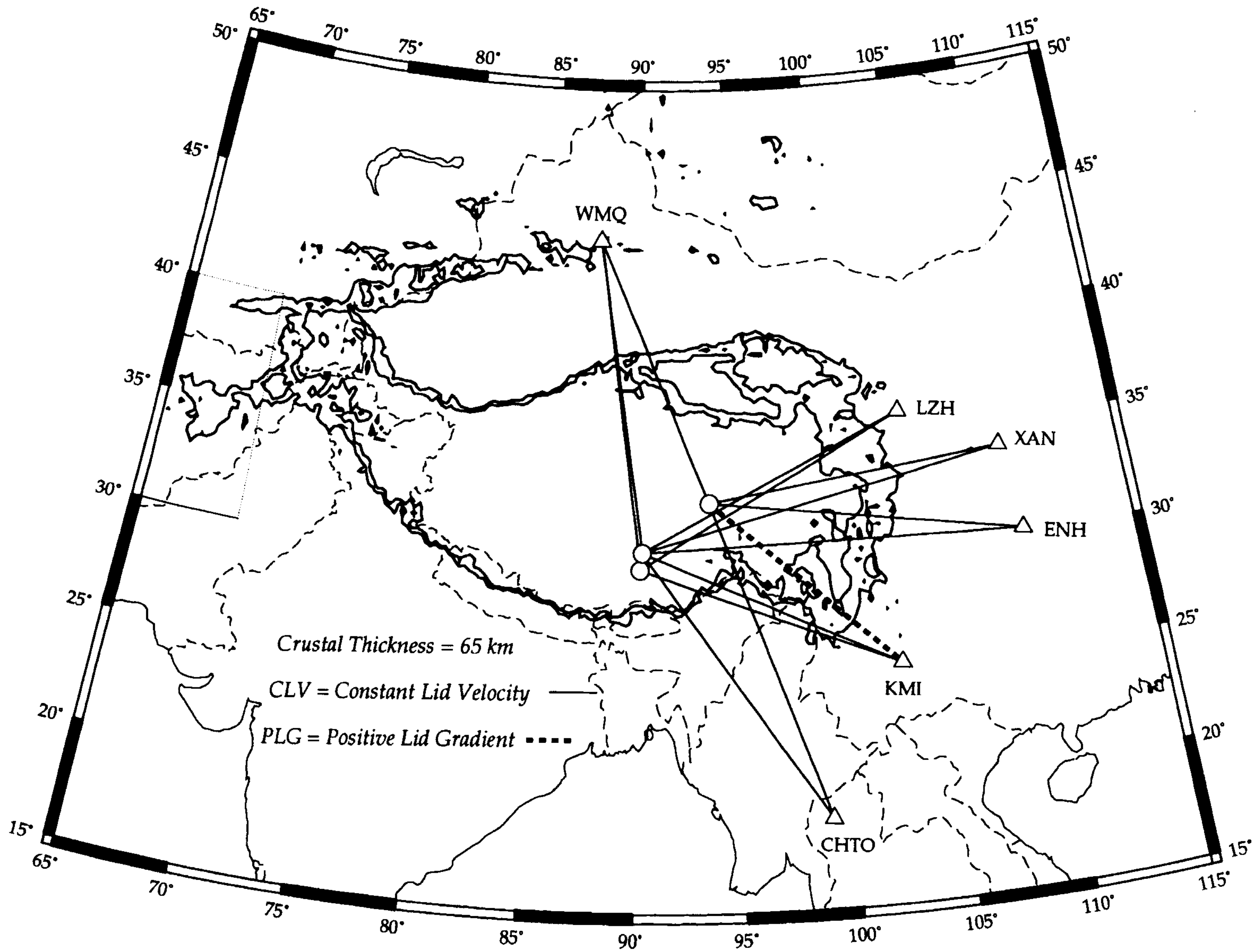


Figure 4. Tibet Events and Paths (3. & 4. km elevation contours shown)